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Flight Characteristics of *Enoclerus lecontei*, *Temnochila virescens*, and *Tomicobia tibialis* in Central California

(Coleoptera: Cleridae, Ostomidae; Hymenoptera: Pteromalidae)

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Field experiments on the response of some predators and parasites of bark beetles to various chemical attractants (Rice, 1969) provided opportunities to observe diurnal flight patterns and flight ranges of these insects. Sex ratios of responding insects were also calculated. The predators *Enoclerus lecontei* (Wolcott) (Coleoptera: Cleridae), and *Temnochila virescens chlorodia* (Mannerheim) (Coleoptera: Ostomidae), and the parasite *Tomicobia tibialis* Ashmead (Hymenoptera: Pteromalidae), were studied at the Boyce Thompson Institute Forest Research Laboratory, Grass Valley, California, during 1965 and 1966.

All observations and experiments were performed in the Boyce Thompson experimental forest at elevations of 2,200 to 2,500 feet. The forest stand is comprised primarily of second growth ponderosa pine, *Pinus ponderosa* Lawson, intermixed with incense cedar, *Libocedrus decurrens* Torr., sugar pine, *Pinus lambertiana* Dougl., and Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco. Occasional stands of California black oak, *Quercus kelloggii* Newb. are also present. Prevailing winds during the summer months are generally upslope from the southwest, varying from 0 to 5 mph during the day.

Flying insects were normally collected in field olfactometers (Vité, Gara and Kliefoth, 1963) which were baited with chemical attractants or with bark beetles feeding in logs. Counts were made hourly and all insects collected were removed from the trapping area to avoid influencing later collections. For flight range and dispersal studies, the two predator species were marked by spraying the chilled, immobile insects with fluorescent aerosol paints (Chapman, 1966) just prior to release.

DIURNAL FLIGHT CHARACTERISTICS

ENOCLERUS LECONTEI (Wolcott).—Hourly collections of *E. lecontei* attracted to traps baited with male *Ips confusus* (LeConte) were made from sunrise until dark on several days during 1965 and 1966.

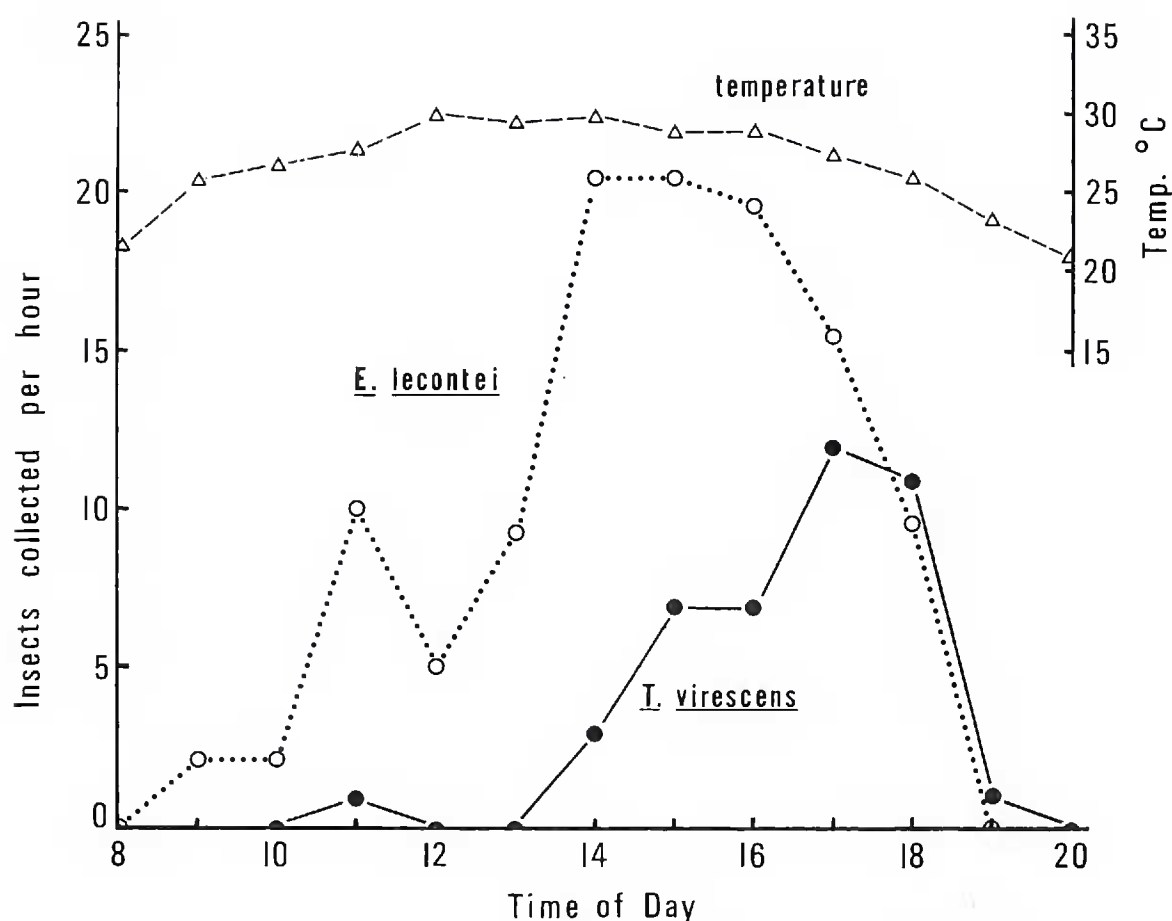


FIG. 1. Diurnal flight patterns of *Enoclerus lecontei* and *Temnochila virescens*. 28 August 1965; Grass Valley, California.

The diurnal flight pattern for *E. lecontei* (Fig. 1) is characteristic of the flights observed for this insect throughout the summer collecting periods. Flight normally started during morning hours when the temperature approached 23° C. The number of clerids collected would build up to a small peak at approximately 1100 hours then decrease toward midday. During the early afternoon clerid flight again increased and reached a maximum at approximately 1500 hours. The number decreased as sunset approached; by sundown very few *E. lecontei* were collected regardless of the temperature. Clerids were not collected after dark. During midsummer *E. lecontei* was collected at temperatures as high as 35° C. Minimum temperatures at which this predator was collected were in the range of 21° to 22° C. These collections occurred during midday in late October.

The sex of attracted *E. lecontei* was determined using the method of Berryman (1966). Of 116 clerids field-collected on 8 and 9 June 1966, 66 were males, 50 were females, for a sex ratio of 1.3 males to 1.0 female. A Chi-square test indicates that this ratio is not statistically significant however, and a 1:1 sex ratio should be expected.

TEMNOCHILA VIRESCENS (Mannerheim).—The collections from three olfactometers for one day were pooled in order to provide sufficient data on the diurnal flight of *T. virescens*. One olfactometer was baited with 200 *I. confusus* males in ponderosa pine logs, one with turpentine, and the third with *n*-heptane. The turpentine and heptane were placed in 50 ml beakers containing 40 ml of dry packed ponderosa pine sawdust soaked to saturation with the liquids.

A characteristic flight pattern (Fig. 1) is shown for *T. virescens*. During the two summers of field work at Grass Valley, only slight activity by ostomids was observed in the morning hours regardless of the temperature. The main flight during summer commenced at approximately 1400 to 1500 hours and reached a peak at about 1700 hours. Ostomids were often collected after sundown when temperatures remained high enough, but were not attracted to the traps after darkness.

In addition to the differing flight patterns shown by collections in olfactometers, the late afternoon and evening activity of *T. virescens* on bark beetle infested trees was considerably greater than that of the clerids. Infested trees were observed during these periods or at night with a flashlight. Ostomids could be found moving rapidly over the bark, while clerids were seldom seen after sundown except when hiding under bark scales. Clerid activity on trees was greater during mid-afternoon and seemed to decrease starting at about 1700 to 1800 hours when the ostomids' greatest flight occurred. Activity of ostomids on the olfactometers was similar to that observed on trees. *Temnochila virescens* attracted to traps during the early afternoon would often seek a crack or hole where they could hide and would then come out after midafternoon and begin feeding on bark beetles lying on the apron of the olfactometer.

Temnochila virescens had previously been observed in flight at temperatures between 24° to 34° C (Gara and Vité, 1962). This predator was collected during this study at temperatures ranging from 21° to 35° C. Overwintered adults collected in the early spring would commence flight when temperatures rose above 21° to 22° C regardless of the time of day. This resulted in peaks of flight during midday rather than in the late afternoon as with adults which emerged during the summer.

The sex of *T. virescens* collected in *Ips confusus* baited olfactometers during portions of the 1965–66 seasons was determined using the method of Struble and Carpelan (1941). Of 760 ostomids sexed, 386 were males, 374 were females, for a 1:1 sex ratio.

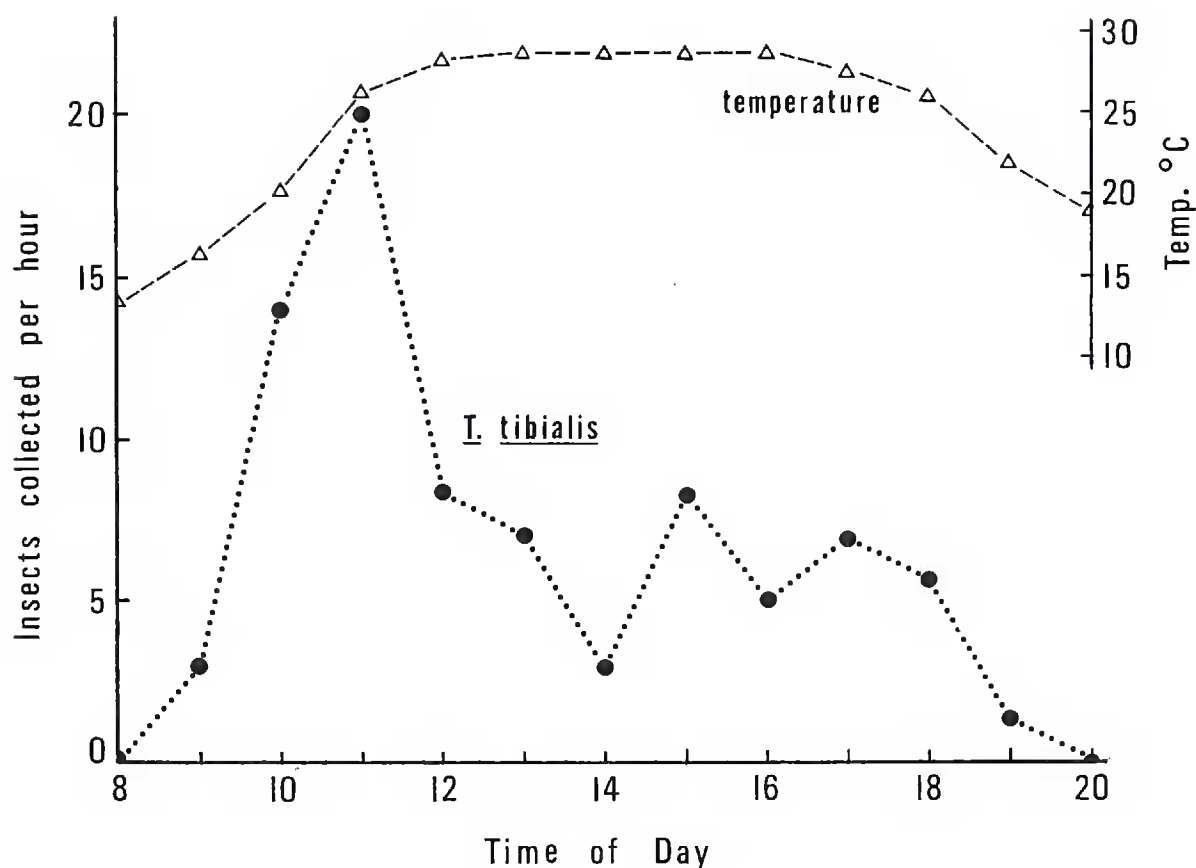


FIG. 2. Diurnal flight pattern of *Tomicobia tibialis*. 7 October 1965; Grass Valley, California.

TOMICOBIA TIBIALIS Ashmead.—The diurnal flight pattern of this parasite was determined by baiting field olfactometers with male *Ips confusus* feeding in ponderosa pine logs. No significant seasonal changes or deviations from the typical flight pattern (Fig. 2) were observed in the field during 1965 and 1966.

The data indicate that *T. tibialis* is capable of initiating flight at approximately 16° C. The number of parasites collected increased with temperature until approximately 1000 to 1100 hours. After this time the numbers collected each hour decreased, reaching the zero point at approximately sunset each day. The sharp midday decrease in collections (Fig. 2) was apparently not due to high temperatures, as similar drops in numbers of responding *T. tibialis* were observed when midday temperatures were only 22° to 23° C. Also, low numbers of the parasites were often collected when midafternoon temperatures were in the range of 33° to 34°C.

It was observed that *T. tibialis* tended to leave the smooth surfaces of the olfactometers as late afternoon approached even though attractive odors were still being emitted. Although these insects were often observed on mass-attacked logs during late afternoon and evening, they

TABLE 1. Changes in the sex ratio of *Tomicobia tibialis* Ashm. collected at different seasons of the year. Grass Valley, California.

Date	Number Collected	Ratio of <i>T. tibialis</i> males : females
1965: Sept. 13	150	1.00 : 2.96
Oct. 8	106	1.00 : 2.54
1966: May 20	72	2.42 : 1.00
24	64	2.54 : 1.00
June 11	42	1.34 : 1.00
27	138	1.00 : 1.38
July 19	62	1.00 : 1.22
Sept. 22	35	1.00 : 2.51

were usually gone from the traps by shortly after sunset. However, they would begin returning by dawn if the temperature was above 16° C.

The sex of *T. tibialis* attracted to *Ips confusus* males was determined on several occasions during this study (Table 1), and showed a striking shift in the ratio between the spring and fall collections.

SEASONAL OCCURRENCES OF PREDATORS AND PARASITES

Temnochila virescens overwinters as an adult and begins flight in the spring with the onset of warm weather (Struble, 1942). This predator

TABLE 2. Summary of predator dispersal studies, Grass Valley, California. 1965 and 1966.

Date Released	Temp. ° C ¹	No. Predators Released	Re-captured	Date Recaptured	Distance from Release (m)
1965: Aug. 31	25 ± 1	120 <i>T. virescens</i>	2	Sept. 1	31
			3	Sept. 2	31
			1	Sept. 3	122
Sept. 11	17 ± 7	75 <i>T. virescens</i>	1	Sept. 15	229
			1	Sept. 22	229
			1	Sept. 23	229
1966: May 2	28 ± 1	356 <i>T. virescens</i>	12	May 3	101
Aug. 9	27 ± 7	140 <i>T. virescens</i>	1	Aug. 10	490 ²
		75 <i>E. lecontei</i>	1	Aug. 10	2094
Aug. 19	23 ± 8	45 <i>T. virescens</i>	1	Aug. 20	730
		40 <i>E. lecontei</i>	1	Aug. 20	730

¹ Daytime temperature mean and range while olfactometers were operating.

² Recaptured downwind from release point; all others upwind.

and six species of bark beetles were observed at Grass Valley in flight and on a mass-attacked log on 31 March 1966. *Temnochila virescens* was subsequently collected in baited traps throughout the spring and summer until mid-October with no complete break in continuity.

Enoclerus lecontei was first collected on 3 May 1966, approximately 5 weeks after the first collections of *T. virescens*. This late emergence and flight probably affects the overall efficiency of *E. lecontei* as a natural control agent on scolytids because this predator is absent during the first bark beetle mass attacks in the spring. Collections of *E. lecontei* continued through October, when trapping was terminated in both 1965 and 1966.

Tomicobia tibialis was collected in olfactometers on 4 April 1966 and thereafter until late October. The number of parasites collected started to decrease sharply from about mid-September on as the maturing larvae began to enter diapause (Bedard, 1965) resulting in fewer numbers of emerging adults.

PREDATOR DISPERSAL

Several releases of marked predators were made to study the long-range dispersal of the two species. Predators marked with different colors of spray paint were released at varying distances from olfactometers baited with *n*-heptane, monoterpenes and *Ips confusus* males in ponderosa pine logs. The released beetles were placed either on logs or on a 2 ft² canvas in direct sunlight and were allowed to fly at will. The results of the dispersal studies are given in Table 2.

It is apparent from these data that movement in the forest of both *T. virescens* and *E. lecontei* can be fairly rapid under favorable weather conditions. Most of the studies were made when daytime temperatures were averaging well above the minimums for good predator activity. Under marginal temperature conditions however, such as experienced following the 11 September 1965 release, movement is much slower, and at least *T. virescens* is capable of remaining in the release area for several days until conditions for flight improve.

DISCUSSION

The three insect species considered in this study are often directed, in response to their various attractants, to exactly the same host location. As a result it might be predicted that a high degree of interspecific competition for hosts could exist between these species. However, it was shown by this study that the diurnal flight characteristics, daily activity

rhythms on trees, and response to environmental factors (such as temperature) of the two predators and the parasite differ considerably. These behavior patterns would tend to separate the three species, thereby reducing competition among them. It would also seem to increase their combined effect on their common scolytid hosts, in that at least one of the three species is actively flying and searching for hosts at any given time of day, given suitable temperatures.

The flight distance-time relationships shown by the two predators were not too unexpected, as both of these species are strong, active fliers. It was somewhat surprising though to find that *T. virescens* would apparently stay in the release area as long as it did (up to 12 days), even under relatively cool temperature conditions.

The reasons for the seasonal shift in the sex ratio of *T. tibialis* are not known at this time. In the way of conjecture, it might be surmised that this is a simple case of arrhenotoky, such as occurs among many other parasitic Hymenoptera. Because of the preponderance of females in the population in the fall, as shown by the data, it would seem logical to assume a similar dominance of diapausing female prepupae in the winter, and female adults in the first spring generation. Relatively low numbers of males in the spring would then tend to let many females go unmated, resulting in a greater proportion of males in the second generation. Such seems to be the case, as shown in the May and early June collections. As the season progressed, however, more females would become mated, resulting in the shift in the late summer and fall back to greater numbers of females. That such a system of parthenogenesis is in fact operating in *Tomicobia tibialis* should be studied in greater detail both in the field and laboratory.

ACKNOWLEDGMENTS

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Insect Distribution Studies II

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Behavior of any species of insect or other organism when introduced into a new territorial environment is often, but not always, inconsistent with its previous history. A careful study of distributional data along with behavioral phenomena of introduced insects is at the same time very interesting and frustrating. When conclusions are reached, although these can be only tentative, they may be helpful in learning to live with the introduced pest species.

An earlier study (Allen, 1963) analyzed the history of olive scale in the United States, and included essential background material applicable to this and future efforts. This paper will attempt to bring up to date the history and distributional patterns of several more introduced insects. Coverage will be limited to California. This will not be so lengthy as the work on olive scale; partly because the patterns seem less complicated, and partly in the interest of covering more species. Species to be considered here are unrelated but have the following in common: (1) They have all been introduced into California within the last 75 years. (2) They have attracted considerable attention as actual or potential plant pests. (3) They have been in California long enough that a pattern is discernible.